R-WD-07-36

Development and analysis of a Target Fish Community model to assess the biological integrity of the Lamprey Designated River, New Hampshire, and to identify indicator fish species for a MesoHABSIM model

Prepared by
Jeffrey D. Legros
and
Piotr Parasiewicz

Northeast Instream Habitat Program **and** ***Rushing Rivers Institute***
Email: jlegros@rushingrivers.com

for

Watershed Management Bureau
New Hampshire Department of Environmental Services
29 Hazen Drive
Concord, NH 03302-0095

www.des.nh.gov

Thomas S. Burack
Commissioner

Michael Walls
Assistant Commissioner

Harry T. Stewart, P.E.
Director, Water Division

June 2007

Development and analysis of a Target Fish Community model to assess the biological integrity of the Lamprey Designated River, New Hampshire, and to identify indicator fish species for a MesoHABSIM model

Prepared by

Jeffrey D. Legros

and

Piotr Parasiewicz

Northeast Instream Habitat Program **and** ***Rushing Rivers Institute***
Email: jlegros@rushingrivers.com

June 2007

Table of Contents

Abstract

As part of a Protected Instream Flow (PISF) study, the Northeast Instream Habitat Program (NEIHP) and Rushing Rivers Institute conducted an assessment of instream habitat under multiple flow conditions within a Designated segment of the Lamprey River, New Hampshire. Within that study a habitat simulation model, MesoHABSIM (Parasiewicz 2001), was used to determine the relationship between instream flow conditions and habitat availability for selected fish species. The analysis entailed the use of multivariate statistics to establish physical habitat characteristics associated with habitat suitability for individual fish species (or species groups). The purpose of that analysis is to provide a means of identifying areas of suitable habitat for select fish species and to assess changes in the sizes and availability of those areas with regard to changes in stream flow conditions. As a component of that PISF study, a Target Fish Community (TFC) model was created to identify the native fluvial fish species considered as indicator species for the MesoHABSIM modeling process. Information from the TFC was used to assess the biological integrity of the Designated segment of the Lamprey River based on a comparative evaluation of the compositions of species and species groups within the TFC and the existing fish community of the Designated River.

The TFC development and analysis processes consisted of multiple steps: First, a list of species expected or with the potential to occur within the study area is compiled and classified based on habitat use, and pollution and thermal regime tolerances. Next, a group of rivers (or river segments) having geomorphic and zoogeographic characteristics similar to those of the Lamprey Designated River are selected as potential references using Geographic Information System (GIS) software. This list of rivers is then filtered based on ecological condition, habitat quality, and the availability of fish collection data to remove those possessing impacted conditions or lacking adequate fish data. The remaining rivers were considered the best available reference rivers for the Lamprey River study area. Existing fish collection data from the reference rivers were subjected to a weighted-ranking procedure to calculate the composition and proportions of fish species within the TFC (Bain and Meixler 2000). Finally, the TFC model was compared to recent fish data collected within the Lamprey Designated River to assess the biological integrity of the study area based on the current condition of the existing fish community.

Overall the Designated River exhibited a fish community that was highly similar to the TFC. A comparative evaluation of the two communities using the percent model affinity approach (Novak and Bode 1992) yielded a 71% affinity index value. Major differences between the two communities were illustrated by an under-abundance of cold-water species and an over-abundance of warm-water species. Additionally, minor differences were revealed by a lower proportion of fluvial specialist species and a greater proportion of macrohabitat generalist species within the existing fish community than the expected TFC proportions. The analysis suggests that the Lamprey Designated River may be affected by macrohabitat conditions conducive to supporting warm-water, macrohabitat generalist species and limiting fluvial specialist species and cold-water species. Based on the overall similarity of the existing fish community to the TFC, the biological integrity of the Designated River appears to be relatively un-impaired. However, the differences between the two communities are indicative of the effects of man-made dams and impoundments present within the Designated River.

Introduction

Target Fish Community (TFC) models have been utilized within instream flow related studies on multiple rivers in Southern New England since Bain and Meixler's initial development and application of the methodology on the Quinebaug River (2000). Successful applications of the approach to assess the status of native fish communities on the Quinebaug, Ipswich, Assabet, Charles, Housatonic, Pomperaug, Souhegan, and Eightmile Rivers (Bain and Meixler 2000, Lang et al. 2001, Armstrong et al. 2001, Parker et al. 2004, Meixler 2005, Kearns et al. 2005, Legros 2007a, Legros 2007b, Parasiewicz et al. 2007) have proven the effectiveness of TFC models as fish community assessment tools. These practical applications illustrate the ability of TFC models to assess the biological integrity of streams using an inference approach based on the biological requirements of fish species (or species groups) and a comparison of their compositions within a TFC and the existing fish community of a study stream (or stream segment). The increasing use and acceptance of this methodology, and similar methods, are indicative of the significance of using fish communities to assess the biological integrity of aquatic systems (Karr 1981, Fausch et al. 1990, Hughes 1995, Halliwell et al. 1999). The past success and recognized importance of the TFC approach has led to its adoption by the Commonwealth of Massachusetts and State of New Hampshire as a component of their water resources policy development processes regarding Protected Instream Flows (PISF).

As a component of a PISF study commissioned by the New Hampshire Department of Environmental Services (NHDES), a TFC was developed to assess the biological integrity of the Designated segment of the Lamprey River and identify indicator fish species for a MesoHABSIM model (Parasiewicz 2001). Development of the TFC was dependent upon the use of fish data from several ecologically healthy Reference River sites that are geomorphically and zoogeographically[1] similar to the Designated segment of the Lamprey River. Defining the model was an interactive process that required direct input from local fisheries experts to assure that the species compositions of the proposed fish community model were conducive to management objectives for the Designated River and consistent with the fish fauna expected to occur within this area. Reference River fisheries data used to calculate the TFC model were provided by various agencies and organizations.

This report presents the Target Fish Community model developed for the Lamprey Designated River. The development and calculation processes are described in detail, the resulting community is given, and a comparative analysis identifying deviations between the expected (TFC) and existing fish community assemblages is illustrated and explained. Potential reasons for such deviations, related to the biological integrity of the study area, are then suggested using an inference-based approach. Inferences are attained based on similarities (or differences) in the compositions and proportions of individual fish species and species groups (with regard to habitat use, pollution tolerance and thermal regime classification guilds) between the expected and existing fish communities. The indicator fish species selected for training of the

[1] Determination of the zoogeographic similarity of areas, or Ecoregions, is based on an analysis of geology, physiography, vegetation, climate, soils, land use, wildlife and hydrology (Omernik 1987).

MesoHABSIM model developed for the Lamprey River PISF study are identified from the TFC.

Methods

Study Area – Designated River

The Lamprey River is a low gradient, low elevation, fourth order, coastal stream which flows 60 miles from the town of Northwood to Newmarket, where it enters Great Bay. The Lamprey drains 212 square miles of the State of New Hampshire's Coastal Watershed. Part of the Lamprey River has been protected by the federal government under the Wild and Scenic Rivers Act. A segment beginning in the town of Epping from the Bunker Pond Dam to the confluence with the Piscassic River in the vicinity of the Durham-Newmarket town line was established under this act. The State of New Hampshire has also identified part of the river for protection. The segment of the Lamprey River between the Epping-Lee town line and the Durham-Newmarket town line was identified as a Designated River in June 1990 by the State of New Hampshire in recognition of its outstanding natural and cultural resources. This Designated segment of the Lamprey River (**Figure 1**) is the focus area of a Protected Instream Flow Study commissioned by the New Hampshire Department of Environmental Services (NHDES) in an effort to establish instream flow standards for the sustainable management and protection of these outstanding resources. The TFC developed as a part of this study and described here is representative of the expected fish community of this area; the reference rivers selected for the development of the TFC, and ultimately the TFC itself, are based on the geomorphic and zoogeographic characteristics of the Lamprey River within the Designated River. Consequently, the TFC is not applicable as a reference for the expected fish communities of any segments of the Lamprey River outside of the Designated River and should not be applied as such.

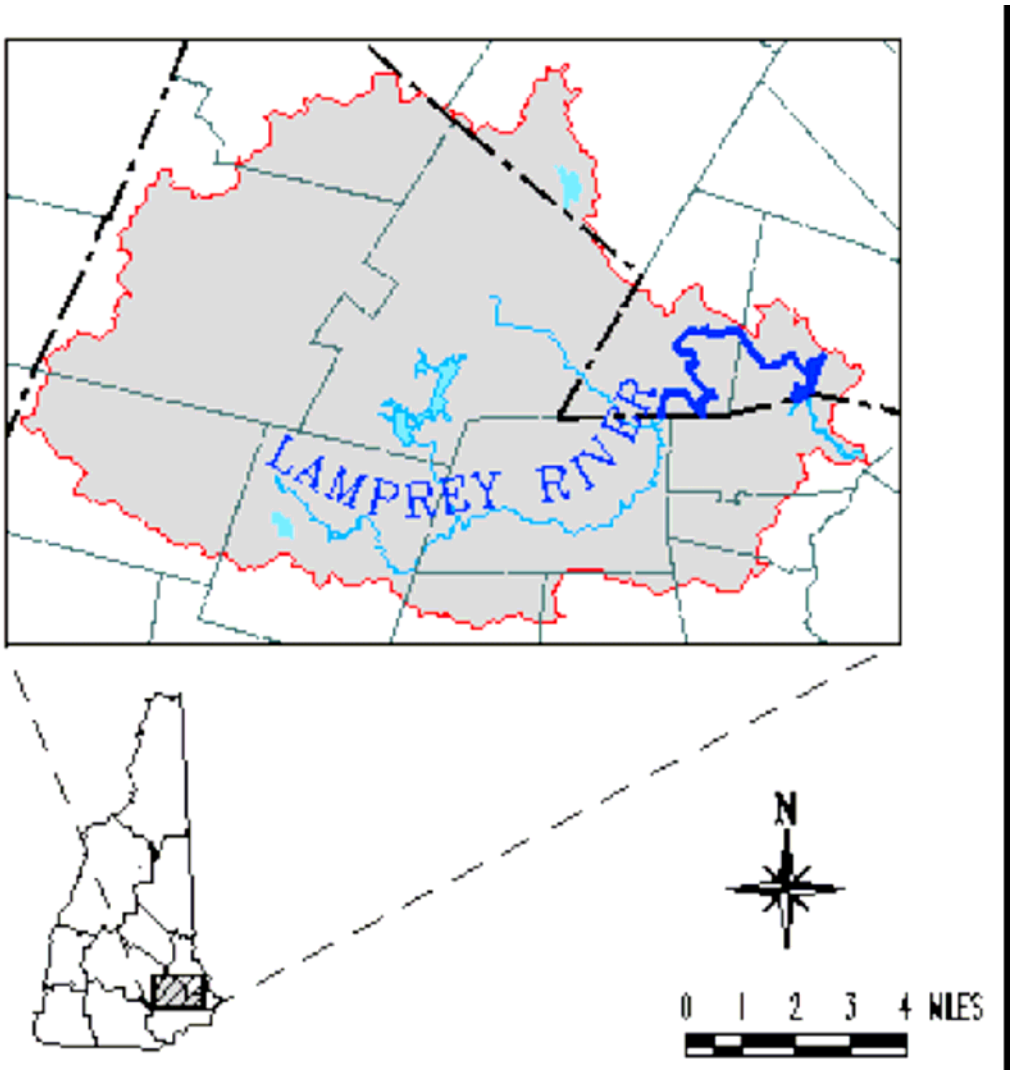

Figure 1. Locus map of the Lamprey River and its watershed. The Designated River is the section shown in bold (NHDES).

Fish List

A comprehensive list of fish species known to occur currently or historically, or with potential to occur, within the Designated River was compiled using literature references of fish distribution, historical and recent observations, and survey collection records (Jackson 1922, NHFGD 1983-1985, Schmidt 1986, Scarola 1987, NHDES 2005, TNC 2006). All species within this list were assigned habitat use classifications based on information compiled by Bain (2000) using regional and state ichthyology books (Scott and Crossman 1973, Pflieger 1975, Lee et al. 1980, Trautman 1981, Becker 1983, Burr and Warren 1986, Robinson and Buchanan 1988, Jenkins and Burkhead 1994). Species were classified as fluvial specialists, fluvial dependents, or macrohabitat generalists based on macrohabitat (water body-type) use requirements. Fish community assessments

conducted based on such guilds have been shown to be effective in relating changes in fish community structure to changes in macrohabitat availability (Bain et al. 1988, Bain and Knight 1996).

Fluvial specialists are species which are almost always associated with flowing-water habitats and require such conditions throughout all major stages of their lifecycle (e.g., fallfish). Fluvial dependents are species that depend on or require access to flowing-water habitats during a particular life-stage or bio-period (e.g., white sucker during spawning). Macrohabitat generalists are species that utilize a variety of macrohabitats from free-flowing rivers and streams to still-water reservoirs, lakes, ponds, impoundments and backwaters and can complete their entire lifecycle in any one of these habitat-types (e.g., redbreast sunfish) (Bain and Travnichek 1996). In this study, as in previous target fish community studies within this region, brook trout, creek chub, fallfish, and longnose dace were reclassified from macrohabitat generalists to fluvial specialists based on their local habitat use patterns (Lang et al. 2001, Kearns et al. 2005). American eel was classified as a macrohabitat generalist. American eel has been classified as a fluvial dependent species in other TFC studies (Bain and Meixler 2000, Meixler 2005). While American eel is a catadromous species and, as such, is dependent upon fluvial conditions for migratory purposes to access the sea to spawn and return to freshwater as a juvenile to live and mature, it is also a habitat generalist and possesses the ability to utilize multiple habitat-types. Within this report we note their fluvial dependency, while classifying them as a macrohabitat generalist for the analyses.

Pollution tolerance classifications were assigned based on the tolerance classifications of the U.S. Environmental Protection Agency (EPA) and Halliwell et al. (1999). Species were classified as intolerant, moderately tolerant, or tolerant of water quality perturbations. Thermal regime classifications were also assigned based on fish species' water temperature tolerances. Fish were classified as cold-water, eurythermal (i.e., tolerating a broad range of temperatures from cold to warm), or warm-water species (Lyons 1996, Halliwell et al. 1999, and Langdon 2001). Finally, species were classified as native or introduced (i.e., exotic) based on their regional and local occurrences, distribution accounts, and hypothesized natal zoogeographic ranges (Lee et al. 1980, Schmidt 1986, Scarola 1987).

Reference River Selection

The initial selection of potential reference rivers was accomplished using ArcInfo® (ESRI, Inc., 1999-2007) GIS software tools. Within ArcMap™, the "*Model Builder*" function was used to create a Reference River Selection Model (RRSM) that would select rivers that were geomorphically and zoogeographically similar to the study river. A selection query was developed within *Model Builder* to select rivers, based on five geomorphic attributes (stream order, size class, elevation class, gradient class, and chemical class) occurring within a pre-defined range of parameters. The quantitative values (i.e., physical measure or range of occurrence) of these attributes were set to match those of the Designated River (**Table 1**). Stream order, size class (watershed size based on drainage area), gradient class, elevation class, and chemical class (percent calcareous geologic formations within upstream watershed) classes are based on ranges

identified by The Nature Conservancy (TNC) and used as attributes to define macrohabitats within a stream classification GIS data layer (TNC 2003, Olivero 2003).

Table 1. Parameters (classes) of the geomorphic and zoogeographic attributes used as criteria within the Reference River Selection Model (RRSM) to define similarity to the Lamprey Designated River.

Reference River Selection Criteria		
Characteristic	**Class**	**Description**
Stream Order	4	Fourth order stream segments
Size Class	2	Watershed area of 30-200 sq. miles
Elevation Class	1	Elevation of 0-800 feet above sea level
Gradient Class	1	Gradient of 0-0.5%
Chemical Class	1	Acidic (<40% calcareous geology for Size Class 2 streams)
Level III Ecoregion	59	Northeastern Coastal Zone

The query was then applied to TNC's "*stream classification data layer*" (TNC 2003, Olivero 2003) to execute a selection of rivers meeting the defined classes of the five geomorphic attributes (i.e., geomorphically similar rivers) (**Figure 2**, "*Output Feature Class*"). Next, this group of potential reference rivers was narrowed based on zoogeographic location, or ecoregion. By projecting a map of Level III Ecoregions (Omernik 1987) with the TNC rivers data layer within ArcMap™, it was determined that the Designated segment of the Lamprey River was within Ecoregion 59, the Northeastern Coastal Zone. In order to eliminate rivers that were not zoogeographically similar to the Designated River, the RRSM was automated to separate the rivers that were located within Ecoregion 59 from those that were not. The resulting output of the model produced a GIS layer, a subset of the original *stream classification data layer*, containing only stream segments which were both geomorphically *and* zoogeographically similar to the Designated River (**Figure 2**, "*Output Feature Class (2)*").

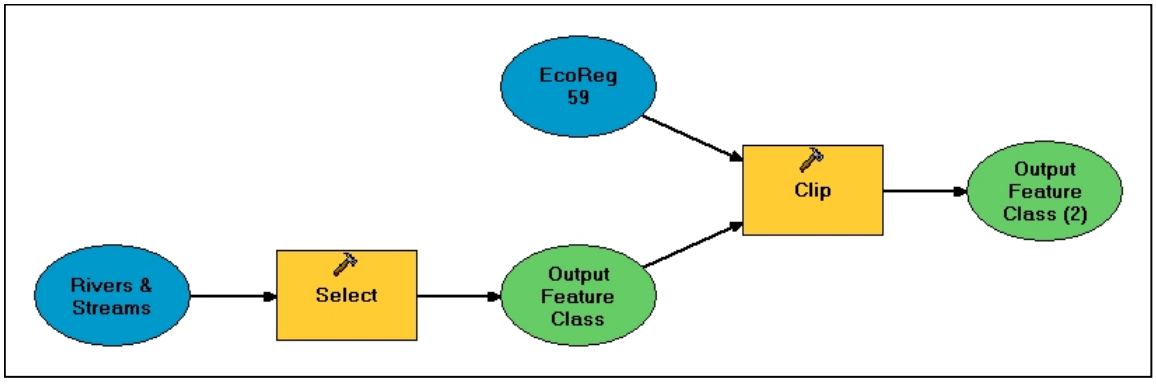

Figure 2. Schematic of the Reference River Selection Model (RRSM).

The ecological condition of these stream segments was then assessed to determine their overall suitability as reference rivers using the definition of Kearns et al. (2005)[2]. Rivers that were deemed to be in poor ecological condition using this definition were eliminated from consideration. The list of potential rivers was further filtered based on the availability and adequacy of fish data. Adequate reference river fish data has been defined in previous TFC studies as data sets originating from at least two sampling locations within free-flowing reaches of a suitable reference river segment and containing at least ten individuals of the most abundant species present (Kearns et al. 2005, Meixler 2005). The remaining rivers, containing adequate fish data and possessing high-quality ecological integrity were designated as reference rivers. Fish data from these rivers were then compiled and utilized for the calculation of the TFC model.

Target Fish Community Development

The New Hampshire Department of Environmental Services (NHDES), New Hampshire Fish and Game Department (NHFGD), Northeast Instream Habitat Program (NEIHP), Massachusetts Division of Fisheries and Wildlife (MADFW), Connecticut Department of Environmental Protection (CTDEP), and Rhode Island Department of Environmental Management (RIDEM) provided the fisheries data used to calculate the TFC model and were instrumental in the development process. Within ArcMap™, geographic coordinates of the fish-data sample sites were used to superimpose sample location points over the selected portions of the reference rivers to determine their exact locations. Fish data that did not originate from within a selected suitable section of a Reference River were not considered in the development of the TFC model.

Following the methods of Bain and Meixler (2000), the total number of fish at each site was summed. The totals of each species were divided by this sum, yielding a proportion of the total catch. These proportions were summed for all sites. The sums of the proportions were then ranked, with the species having the greatest sum ranked "1". At this point all non-native species were removed from the calculation. Although these species were removed, all of the species remaining on the list maintained the same numerical rank. Then, the reciprocal of each species' rank was taken, and these reciprocals were summed. The reciprocal rank of any given species divided by the sum of all reciprocal ranks yielded that species' expected proportion within the TFC.

Lamprey Designated River Existing Fish Community

Comprehensive sampling data collected during the Lamprey River Baseline Fish Sampling Survey between August 25 and August 29, 2003 (NHDES 2005) were used to define the existing fish community of the Lamprey Designated River. Fish collections were conducted at 43 stations using gill nets, shoreline seining, and backpack, barge, and

[2] In a similar analysis on the Housatonic River (Kearns et al. 2004), quality rivers were defined as being "relatively unimpaired, undammed, and undeveloped with few water withdrawals, good water quality, and a similar temperature regime."

boat-mounted electrofishing methods. The Lamprey River Baseline Fish Community survey was designed and implemented to collect a complete, representative sample of resident fish species within the Designated River and took into account the distribution of available macrohabitat types (NHDES 2005). This unique and comprehensive survey design served to strengthen the legitimacy of an evaluation of the existing fish community using the TFC approach. More explicitly, there is a high degree of likelihood that the vast majority of species existing within the Designated River were sampled during this study and that the resulting community is representative of the present macrohabitat conditions, allowing for an accurate and complete comparison with the TFC and assessment of the biological integrity of this area.

Fish Community Evaluation

An evaluation of the current condition of the existing fish community of the Lamprey River was accomplished by comparing the similarity between the TFC and the existing fish community. To make this comparison, we used the Percent Model Affinity procedure developed by Novak and Bode (1992). This procedure yields values from 0 to 100 to describe the extent to which the study river's fish community (i.e., existing or observed fish community) is similar to the TFC. Higher percent model affinity values indicate higher degrees of similarity between the communities. These values are calculated as:

$$\text{Percentage similarity} = 100 - 0.5 \sum \left| \textit{expected}\ \% - \textit{observed}\ \% \right|$$

where *expected* % is the percentage of individuals of a particular species in the TFC and *observed* % is the percentage of the same species in the existing fish community.

Additional similarity comparisons were made between the two communities based on the expected and existing proportions of habitat use, pollution tolerance, and thermal regime tolerance classification guilds using the percent model affinity approach. The absolute differences between proportions of the habitat-use, pollution tolerance, and thermal regime classification guilds of the communities were summed, multiplied by 0.5, and subtracted from 100 to determine the percentage similarity between the two communities based on these classification guilds.

A percent deviation calculation was then conducted for each individual species and for each individual species-group guild to quantify deviations between expected (TFC) and observed community compositions:

$$\text{Percent deviation} = \left| \textit{expected}\ \% - \textit{observed}\ \% \right| / \textit{expected}\ \%$$

Percent deviation was calculated for each species to document under-represented species, over-represented species, and species found in proportions similar to expected proportions. A degree of deviation of 50% or greater was arbitrarily selected to indicate an apparent and substantial departure from expected (TFC) proportions. Species with

observed proportions deviating by more than 50%, either less or greater than the expected (TFC) proportions, were considered under-represented or over-abundant, respectively. Native species identified within the TFC that were missing from the existing fish community, or *vice versa*, and non-native species occurring within the existing community were also identified. Similarly, a percent deviation analysis was conducted for each of the classes within the species-group guilds to quantify deviations at the species-group level.

Results

Fish List

Based on a review of fish distribution references, historical records, and recent collection records, this study found 36 fish species from 12 families occurring either historically or currently within the Designated River. These species were compiled into a list organized by taxonomic classes. Native or introduced status, habitat use, pollution tolerance, and thermal regime classifications are given for each species on the list (**Table 2**). The assemblage contains a variety of species, both native and introduced, with a full range of habitat use, pollution tolerance, and thermal regime classifications.

Reference Rivers

The RRSM identified 64 rivers which are geomorphically and zoogeographically similar to the Designated River (**Appendix**). After these rivers were filtered based on their ecological condition and the availability of fish survey data, four reference rivers remained. In order to account for all of the necessary species required for the development of a robust and representative TFC, two other potential reference rivers (Cocheco and Isinglass Rivers) were included with these four, despite the fact that they possessed minor ecological impairments. Fish data from these reference rivers were then used for the development of the Lamprey Designated River TFC. A quantitative matrix of their geomorphic and zoogeographic characteristics is presented in **Table 3**. The average values of these attributes throughout the Designated River are also given. **Figure 3** is a map illustrating the locations of the selected reference rivers and sample locations of fish data used in the development of the TFC.

Table 2. Expected fish species of the Lamprey Designated River.

Native (N) or introduced (I) statuses, fluvial specialist (FS), fluvial dependent (FD), or macrohabitat generalist (MG) habitat use classifications, intolerant (I), moderately tolerant (M), or tolerant (T) pollution tolerances, and Cold, Eurythermal, or Warm water thermal regime tolerances are given for each species.

FAMILY Common name	*Genus*	*Species*	Native or Introduced	Habitat use classification	Pollution tolerance	Thermal regime
Petromyzontidae						
Sea lamprey	*Petromyzon*	*marinus*	N	FD	M	Eurythermal
Anguillidae						
American eel	*Anguilla*	*rostrata*	N	MG*	T	Eurythermal
Clupeidae						
Blueback herring	*Alosa*	*aestivalis*	N	FD	M	Warm
Alewife	*Alosa*	*pseudoherangus*	N	FD	M	Eurythermal
American shad	*Alosa*	*sapidissima*	N	FD	M	Warm
Salmonidae						
Rainbow trout	*Oncorhynchus*	*mykiss*	I	FD	I	Cold
Atlantic salmon	*Salmo*	*salar*	N	FS	I	Cold
Brown trout	*Salmo*	*trutta*	I	FD	I	Cold
Brook trout (char)	*Salvelinus*	*fontinalis*	N	FS	I	Cold
Escocidae						
Redfin pickerel	*Esox*	*americanus*	N	MG	M	Warm
Chain pickerel	*Esox*	*niger*	N	MG	M	Warm
Cyprinidae						
Common shiner	*Luxilus*	*cornutus*	N	FD	M	Eurythermal
Golden shiner	*Notemigonus*	*crysoleucas*	N	MG	T	Eurythermal
Bridle shiner	*Notropis*	*bifrenatus*	N	MG	I	Warm
Spottail shiner	*Notropis*	*hudsonius*	I	MG	M	Eurythermal
Blacknose dace	*Rhinichthys*	*atratulus*	N	FS	T	Eurythermal
Longnose dace	*Rhinichthys*	*cataractae*	N	FS	M	Eurythermal
Creek chub	*Semotilus*	*atromaculatus*	N	FS	T	Eurythermal
Fallfish	*Semotilus*	*corporalis*	N	FS	M	Eurythermal
Catostomidae						
Common white sucker	*Catostomus*	*commersoni*	N	FD	T	Eurythermal
Creek chubsucker	*Erimyzon*	*oblongus*	N	FS	I	Eurythermal
Ictaluridae						
Yellow bullhead	*Ameiurus*	*natalis*	I	MG	T	Warm
Brown bullhead	*Ameiurus*	*nebulosus*	N	MG	T	Warm
Cyprinodontidae						
Banded killifish	*Fundulus*	*diaphanus*	N	MG	T	Warm
Moronidae						
White perch	*Morone*	*americana*	N	MG	M	Eurythermal
Striped bass	*Morone*	*saxitilis*	N	FD	M	Warm
Centrarchidae						
Rock bass	*Amblopites*	*rupestris*	I	MG	M	Eurythermal
Banded sunfish	*Enneacanthus*	*obesus*	N	MG	M	Warm
Redbreast sunfish	*Lepomis*	*auritus*	N	MG	M	Warm
Pumpkinseed	*Lepomis*	*gibbosus*	N	MG	M	Warm
Bluegill	*Lepomis*	*macrochirus*	I	MG	T	Warm
Smallmouth bass	*Micropterus*	*dolomieu*	I	MG	M	Eurythermal
Largemouth bass	*Micropterus*	*salmoides*	I	MG	M	Warm
Black crappie	*Pomoxis*	*nigromaculatus*	I	MG	M	Warm
Percidae						
Swamp darter	*Etheostoma*	*fusiforme*	N	MG	M	Warm
Yellow perch	*Perca*	*flavescens*	N	MG	M	Eurythermal

*American eel have been classified as *fluvial dependent* in other TFC due to this species dependency upon fluvial conditions for migration to and from the sea to complete their catadromous life-cycle.

Table 3. Selected reference river fish sampling stations and their geomorphic and zoogeographic characteristics. Average values of these characteristics throughout the Lamprey Designated River are also given.

River	Agency	Site I.D.	Stream Order	Drainage Area	Average Elevation	Gradient	% Calcareous Geology	Level III EcoRegion
Lamprey River	**NA**	**NA**	**4**	**160**	**15.4**	**0.001**	**33.4**	**59**
Cocheco River	NHDES	98P-50	4	49	74.5	0.0019	0	59
Cocheco River	NHDES	98P-51	4	59	68	0	0	59
Cocheco River	NHDES	00P-45	4	64	61	0.0024	0	59
Cocheco River	NHDES	98P-52	4	95	37.5	0.0014	1	59
Eightmile River	NEIHP	8	4	46	13.5	0.0022	0	59
Eightmile River	NEIHP	10	4	56	7	0.0047	0	59
Eightmile River	NEIHP	10	4	56	7	0.0047	0	59
Fort River	MADFW	443	4	43	38.5	0.0014	0	59
Fort River	MADFW	442	4	37	45	0.002	0	59
Isinglass River	NHFGD	ST027	4	41	77.5	0.0061	0	59
Isinglass River	NHDES	98P-54, 98P-54-06	4	57	53	0.0027	2	59
Isinglass River	NHDES	98P-53	4	64	36.5	0.0031	4	59
Nissitissit River	MADFW	1087	4	52	63	0	19	59
Nissitissit River	MADFW	1089, 1090	4	60	58	0.0028	30	59
Wood River	RIDFW	4, 2, 32	4	75	21	0.0011	0	59

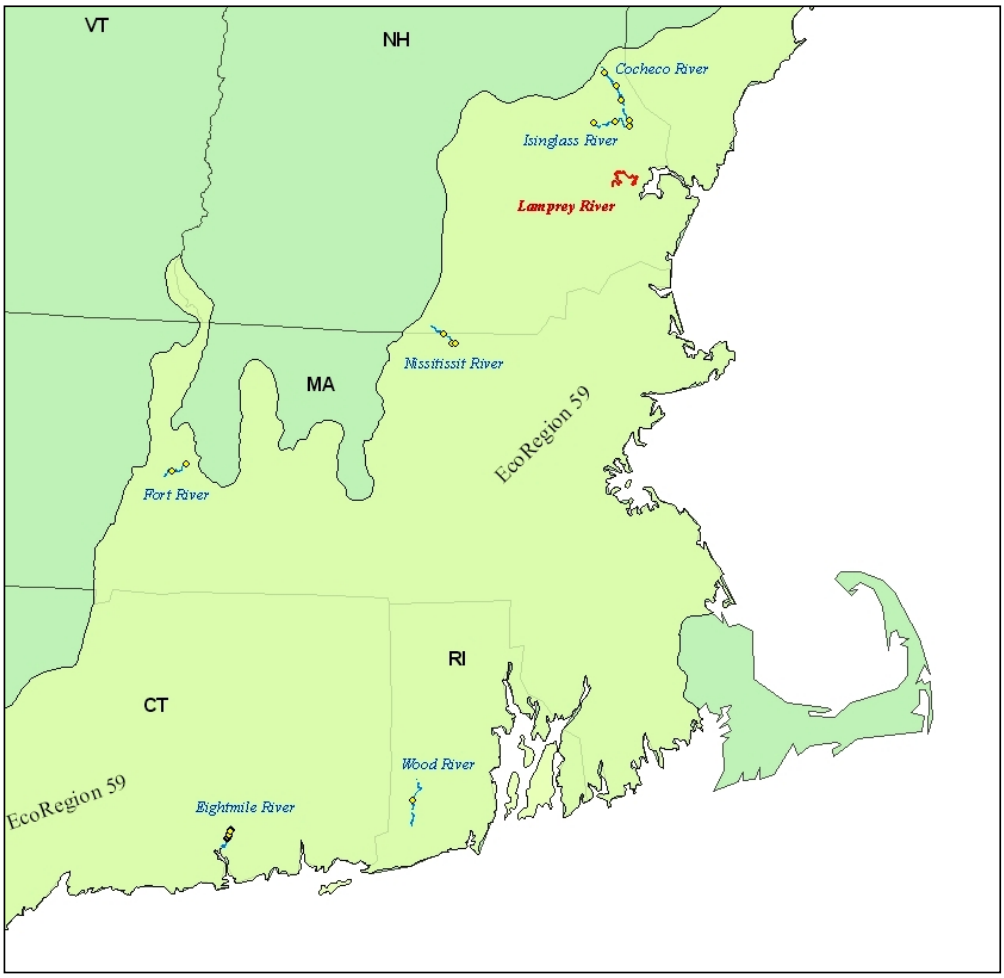

Figure 3. Selected reference rivers and fish data sample locations for the Lamprey Designated River Target Fish Community (TFC).

Lamprey Designated River Target Fish Community

The reference rivers' fish data used to calculate the ranks and expected proportions of species within the TFC developed for the Lamprey Designated River are presented in **Table 4** (scientific names of fish species can be found within **Table 2**). Species found in the reference rivers which are not native to the Lamprey River watershed were ranked, but were not given proportions. The TFC consists of a diverse fish fauna of 18 species dominated by common shiner (31%), fallfish (16%), American eel (10%), common white sucker (8%), longnose dace (6%), redbreast sunfish (5%), pumpkinseed (4%), blacknose dace (3%), chain pickerel (2%), and Atlantic salmon (2%). The remaining 12% of the community was comprised of eight species (yellow perch, brown bullhead, creek chubsucker, redfin pickerel, bridle shiner, brook trout, creek chub, and swamp darter) having individual proportions ranging between 1% and 2% (**Table 5**, **Figure 4**). Four anadromous species (Alewife, American shad, blueback herring, and sea lamprey), listed in **Table 5** are also a component of the TFC. While specific proportions could not be calculated for these species they are expected to occur within the Lamprey Designated River. The TFC is composed of 31% fluvial specialist, 39% fluvial dependent, and 30% macrohabitat generalist species (**Figure 5**).

Table 4. Reference River fish data and mean rankings used to calculate expected proportions of fish species within the Lamprey Designated River TFC.

Reference Rivers: **Common Name**	**Bio-geographic Status***	**Cocheco River**	**Eightmile River**	**Fort River**	**Isinglass River**	**Nissitissit River**	**Wood River**	**Mean Rank**
Common Shiner	Native	33	130	1	168	85	197	1
Fallfish	Native	4	22	49	94	137	25	2
American Eel	Native	43	62	24	102	8	36	3
Common White Sucker	Native	22	35	33	4	122	13	4
Longnose Dace	Native	53	7	4	67	40	76	5
Redbreast Sunfish	Native		76		58		98	6
Tessellated Darter	Non-native		121				83	7
Pumpkinseed	Native	13	23	1	13	38	2	8
Spottail Shiner	Non-native	17	79					9
Blacknose Dace	Native	2	24			49		10
Largemouth Bass	Non-native	4	42		6	9	1	11
Bluegill	Non-native	1	3		17	5	30	12
Chain Pickerel	Native	2	1		9	31	7	13
Atlantic Salmon	Native		10		18		17	14
Rock Bass	Non-native			9				15
Smallmouth Bass	Non-native		9	5	2	1		16
Yellow Perch	Native	1	30		2	2		17
Brown Bullhead	Native		1		7	5	5	18
Rainbow Trout	Non-native	1		2		2	1	19
Creek Chubsucker	Native				1	6	8	20
Redfin Pickerel	Native	3	6					21
Central Mudminnow	Non-native		14					22
Yellow Bullhead	Non-native	1				7		23
Bridle Shiner	Native				9			24
Brook Trout	Native		2				5	25
Margined Madtom	Non-native				5			26
Brown Trout	Non-native						4	27
Sea Lamprey	Native		3					28
Creek Chub	Native				2			29
Swamp Darter	Native				1			30
Black Crappie	Non-native						1	31
Totals:		200	700	128	585	547	609	

*Native or non-native statuses given here are specific to the Lamprey River watershed.

Table 5. Definition of the Lamprey Designated River TFC as calculated from the rankings of the reference river fish species native to the Lamprey watershed. Definitions of abbreviated terms are given within Table 2 caption.

Common Name	Species Designation	Habitat Use Class	Pollution Tolerance	Thermal Regime	Expected Proportion
Common Shiner	Native	FD	M	Eurythermal	31%
Fallfish	Native	FS	M	Eurythermal	16%
American Eel	Native	MG	T	Eurythermal	10%
Common White Sucker	Native	FD	T	Eurythermal	8%
Longnose Dace	Native	FS	M	Eurythermal	6%
Redbreast Sunfish	Native	MG	M	Warm	5%
Pumpkinseed	Native	MG	M	Warm	4%
Blacknose Dace	Native	FS	T	Eurythermal	3%
Chain Pickerel	Native	MG	M	Warm	2%
Atlantic Salmon	Native	FS	I	Cold	2%
Yellow Perch	Native	MG	M	Eurythermal	2%
Brown Bullhead	Native	MG	T	Warm	2%
Creek Chubsucker	Native	FS	I	Eurythermal	2%
Redfin Pickerel	Native	MG	M	Warm	2%
Bridle Shiner	Native	MG	I	Warm	1%
Brook Trout	Native	FS	I	Cold	1%
Creek Chub	Native	FS	T	Eurythermal	1%
Swamp Darter	Native	MG	M	Warm	1%
Alewife	Native	FD	M	Eurythermal	Expected
American Shad	Native	FD	M	Warm	Expected
Blueback Herring	Native	FD	M	Warm	Expected
Sea Lamprey	Native	FD	M	Eurythermal	Expected
Totals:					100%

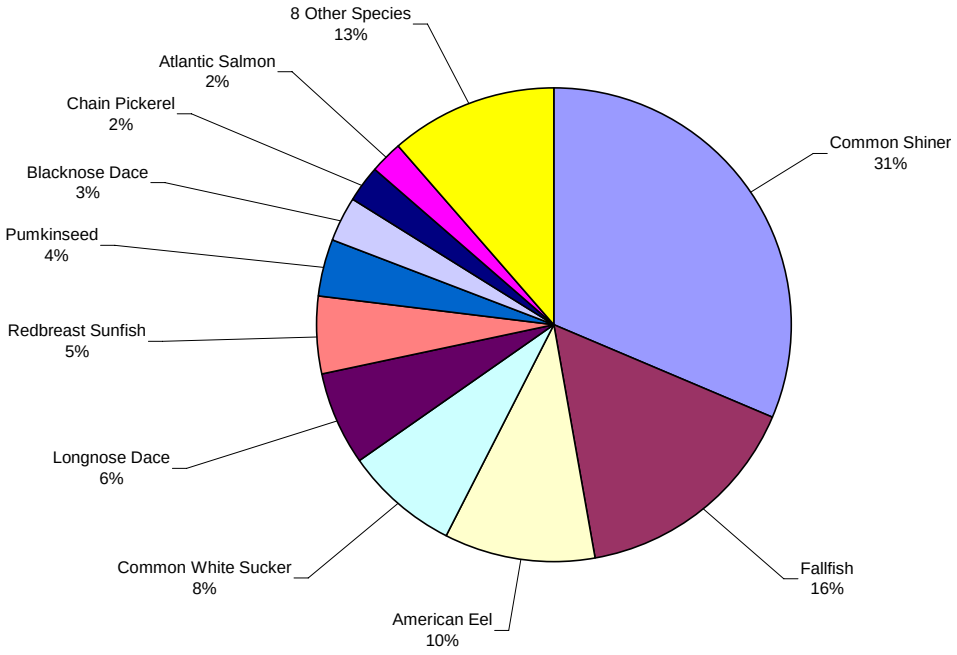

Figure 4. Lamprey Designated River TFC.

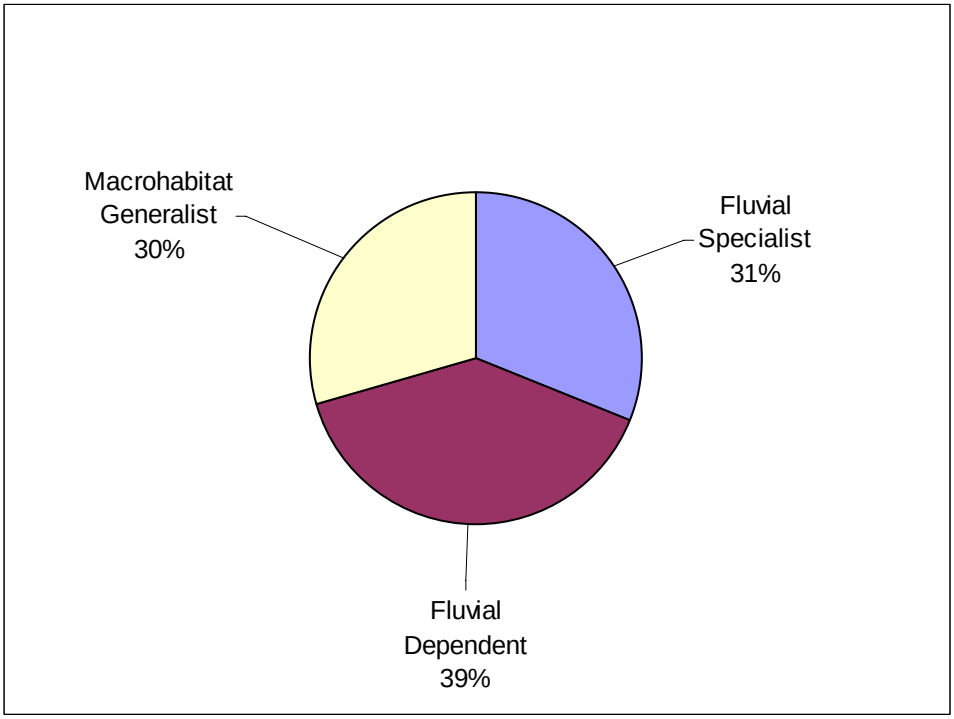

Figure 5. Lamprey Designated River TFC composition by habitat-use classification guilds.

Lamprey Designated River Existing Fish Community

The existing fish community of the Lamprey Designated River, as sampled during the Lamprey River Baseline Fish Sampling Survey of August 25-29, 2003 (see NHDES 2005), consisted of common shiner (34%), redbreast sunfish (15%), fallfish (12%), pumpkinseed (6%), bluegill (6%), common white sucker (5%), American eel (5%), longnose dace (5%), golden shiner (4%), smallmouth bass (2%), largemouth bass (2%), yellow perch (1%), bridle shiner (1%), yellow bullhead (1%), chain pickerel (1%), and 11 other species (creek chubsucker, alewife, blacknose dace, black crappie, rock bass, Atlantic salmon, brown bullhead, redfin pickerel, brown trout, blueback herring, and rainbow trout) comprising the remaining 2% of the community (**Table 6, Figure 6**). The existing fish community consisted of 18% fluvial specialists, 39% fluvial dependent, and 43% macrohabitat generalists (**Figure 7**). A total of 26 different fish species were sampled from the Lamprey River, 18 of which were native. Eight non-native fish species, bluegill, black crappie, brown trout, largemouth bass, rainbow trout, rock bass, smallmouth bass, and yellow bullhead were sampled and accounted for a combined 11% of the community.

Table 6. Lamprey Designated River existing fish community data (NHDES).

Section I.D. **Common Name**	**Section 1**	**Section 2**	**Section 3**	**Section 4**	**Section 5**	**Section 6**	**Section 7**	**Section 8**	**Existing Proportion**
Common Shiner	275	613	512	325	359	9	47		34%
Redbreast Sunfish	97	226	179	109	59	84	184	10	15%
Fallfish	37	301	94	94	130	35	76		12%
Pumpkinseed	87	60	104	24	51		4	47	6%
Bluegill		1	16					341	6%
Common White Sucker	134	59	85	17	24	2	1	2	5%
American Eel	9	45	37	22	9	45	104	17	5%
Longnose Dace		90	3	126	53	12	3		5%
Golden Shiner	120	26	42		47			4	4%
Smallmouth Bass		10	24	42	33	13	3	3	2%
Largemouth Bass	1	3	4	3	35	4	1	44	2%
Yellow Perch	1	15	19	6	16			20	1%
Bridle Shiner	39	13	2						1%
Yellow Bullhead	9	19	5	2	16				1%
Chain Pickerel	1	3	13		11			10	1%
Creek Chubsucker	9	1	12						<1%
Alewife	2	1			18				<1%
Blacknose Dace	19								<1%
Black Crappie								18	<1%
Rock Bass	18								<1%
Atlantic Salmon		5		5	3				<1%
Brown Bullhead			5	4	2				<1%
Redfin Pickerel	3		1					2	<1%
Brown Trout				1	2				<1%
Blueback Herring	1		1						<1%
Rainbow Trout			1						<1%
Totals:	862	1491	1159	780	868	204	423	518	100%

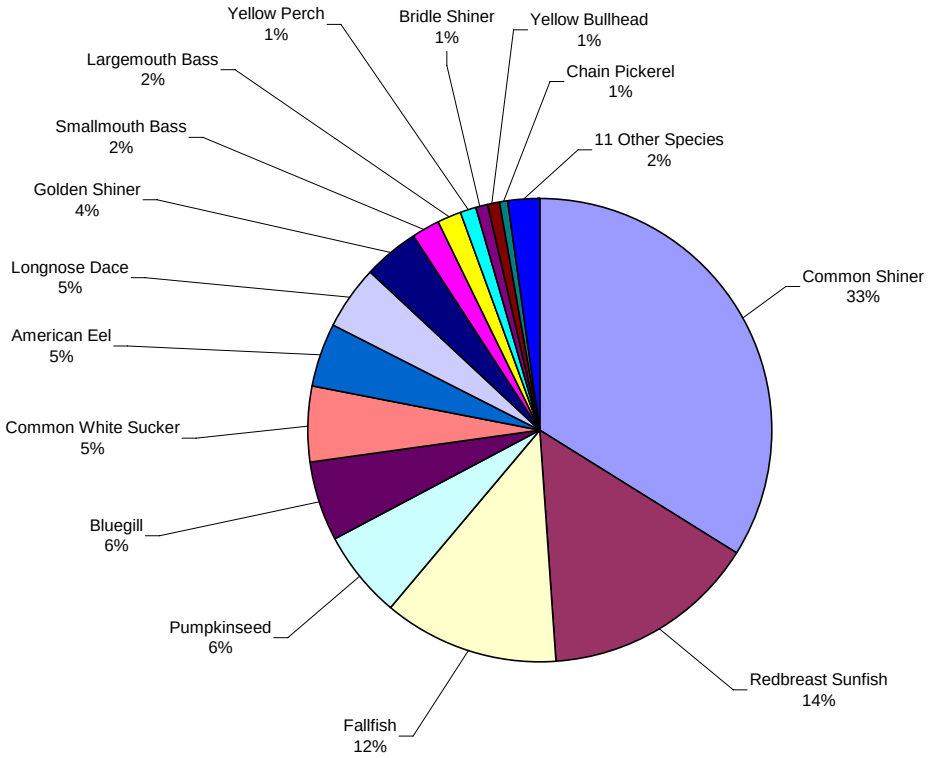

Figure 6. Lamprey Designated River Existing Fish Community.

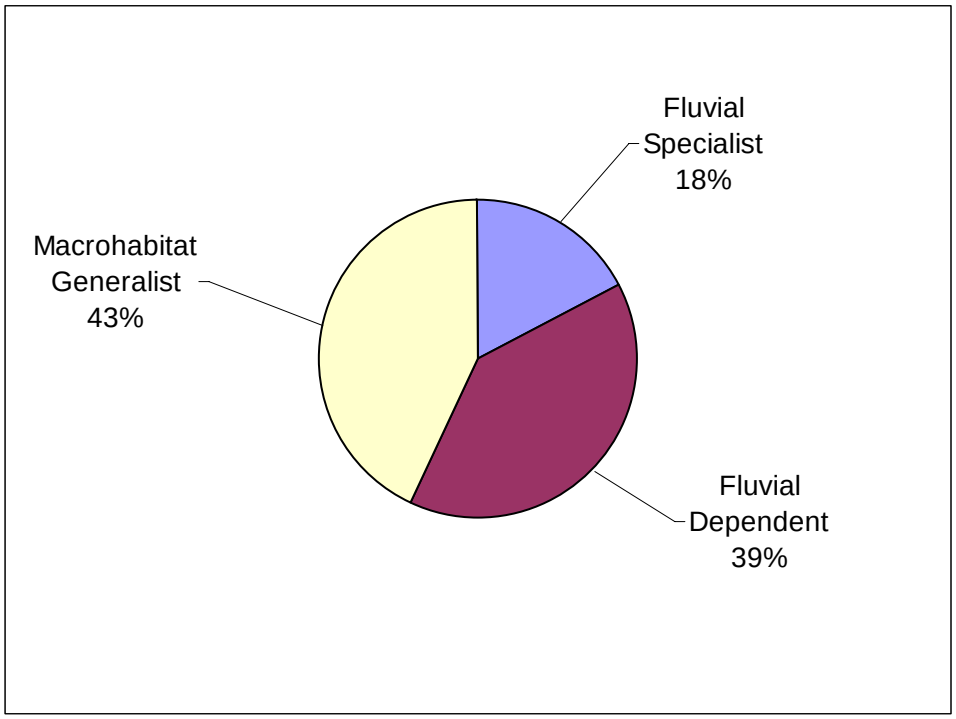

Figure 7. Lamprey Designated River Existing Fish Community composition by habitat-use classification guilds.

Fish Community Evaluation

The overall affinity of the existing fish community to the TFC model was 71%. Comparison of the existing fish community and TFC based on habitat-use guilds showed a close match between the two communities (**Figure 8**). Proportions of fluvial dependent species were the same in both communities (39%). Differences between the two communities are apparent in the minor over-abundance of macrohabitat generalist species and under-abundance of fluvial specialist species within the existing fish community. Proportions of these species within the target and existing communities are presented in the sections describing the TFC and existing fish community and in **Figures 5 & 7**. The percent model affinity calculated for the two communities' habitat-use classification guilds showed 86% similarity.

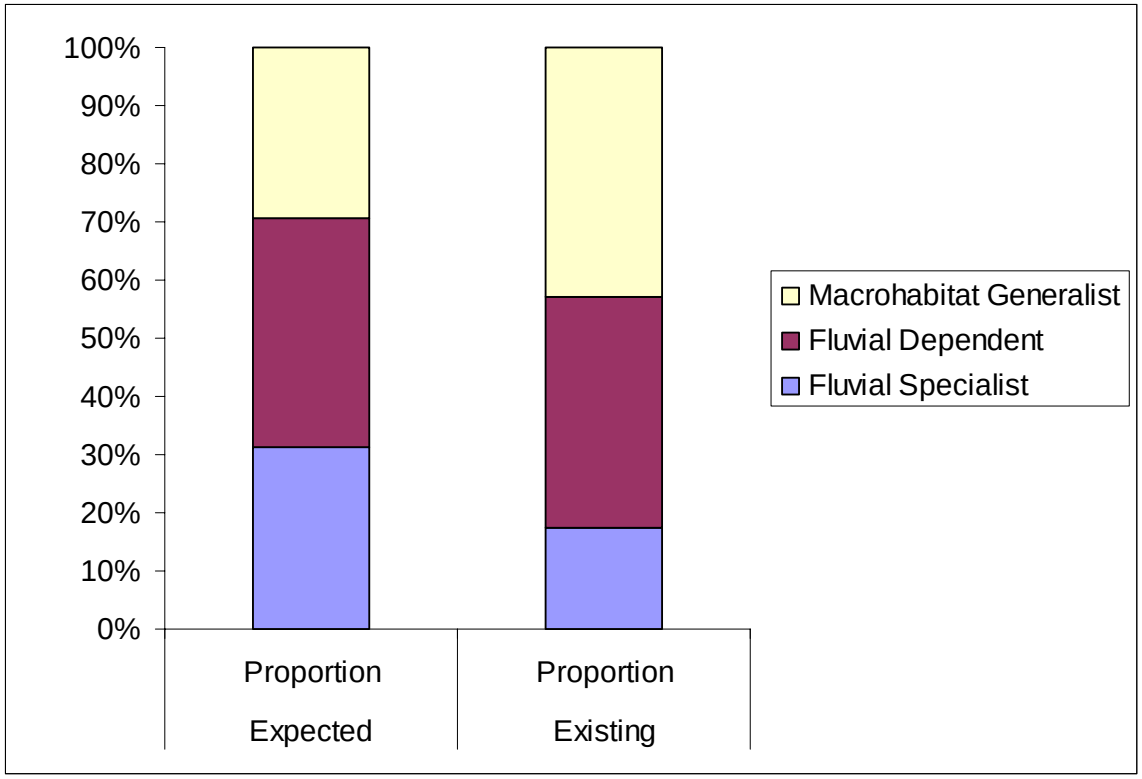

Figure 8. Comparison of the expected (TFC) and existing fish communities based on habitat-use classification guilds.

The comparison of the proportions of fish species pollution tolerance classification guilds of the existing fish community (20% tolerant, 78% moderately tolerant, and 2% intolerant species) to those of the TFC (24% tolerant, 69% moderately tolerant, and 7% intolerant species) showed a considerable under-representation of pollution intolerant species within the existing fish community. Differences between pollution tolerant and moderately tolerant species, however, were minor (**Figure 9**). Overall, the communities scored a 91% model affinity value based on the similarity between the proportions of pollution tolerance classification guilds of the two communities.

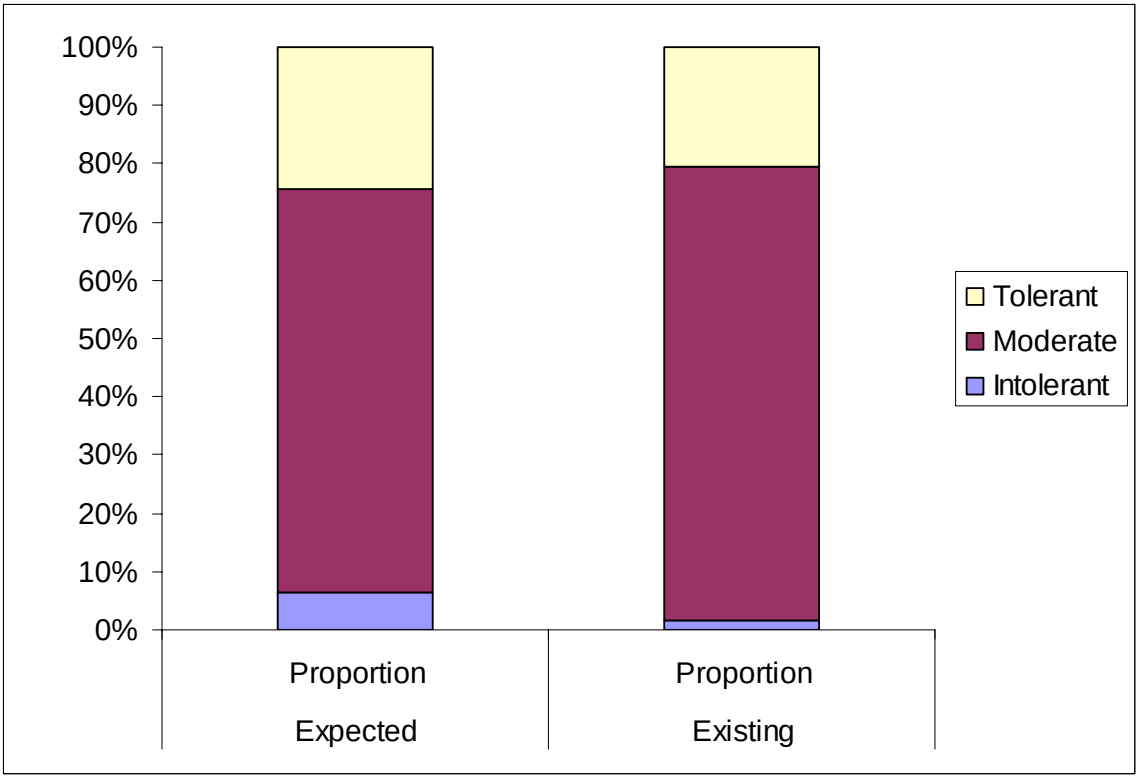

Figure 9. Comparison of the expected (TFC) and existing fish communities based on pollution tolerance classification guilds.

When the TFC and existing fish community were compared based on the proportions of thermal regime tolerance guilds of fish species, considerable differences were observed (**Figure 10**). The existing fish community consisted of 31% warm, 69% eurythermal, and 0.2% cold-water fish species (Atlantic salmon [*n*=13], brown trout [*n*=3], and Rainbow trout [*n*=1]). Eurythermal fish species existed in a proportion somewhat similar to the expected proportion of the TFC (69% *vs.* 79%). The proportion of warm-water species was considerable higher than the expected proportion of 17%. Conversely, the proportion of cold-water species was much lower than the expected proportion of 4% and nearly absent from the existing community. When a percent model affinity similarity measurement was applied to the existing fish community and TFC thermal regime classification guild proportions a value of 86% was calculated.

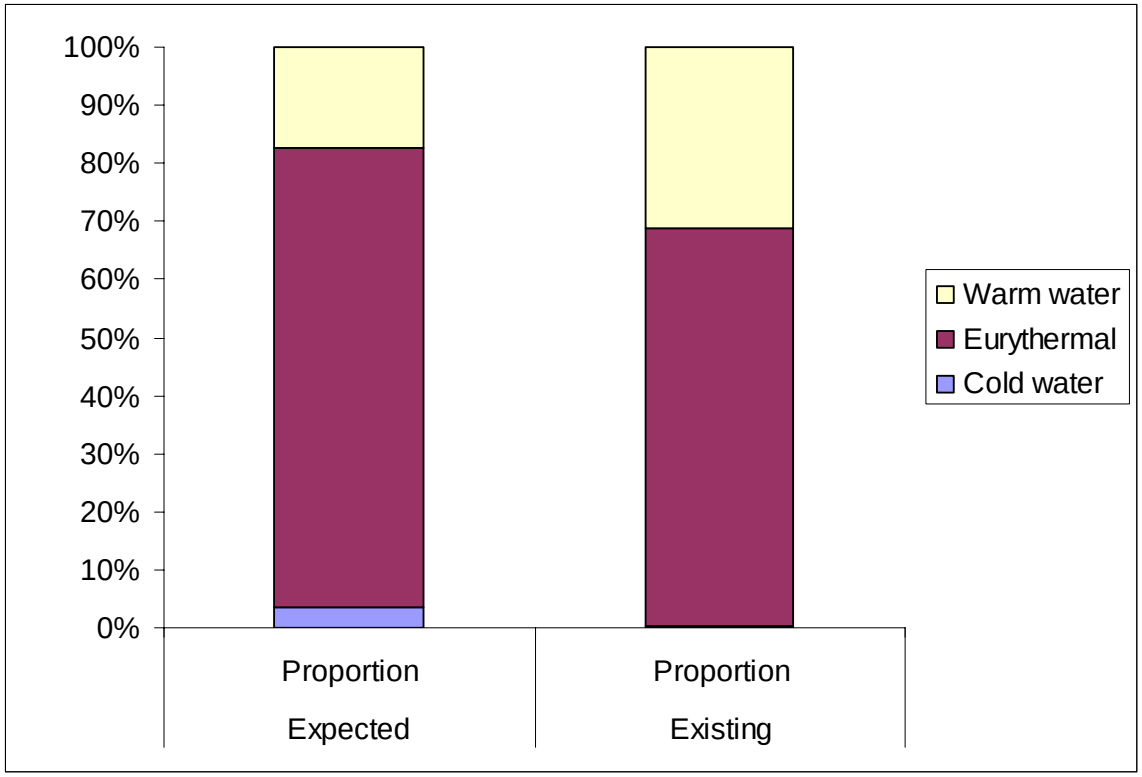

Figure 10. Comparison of the expected (TFC) and existing fish communities based on thermal regime classification guilds.

Within the Designated segment of the Lamprey River, seven native species are considered under-represented and two are over-abundant. Six species are found in proportions similar to those expected by the TFC, while three species are absent. There are eight non-native fish species occurring in the Designated River. Non-native species are not a part of the TFC; consequently, these species were considered over-abundant within this analysis. One native fish species which was not a member of the TFC, golden shiner, was sampled within the Designated River. Two out of the six diadromous species expected to occur within the Lamprey River were sampled within the existing fish community (**Table 7**).

Table 7. Comparison of proportions of fish species between the TFC and the existing fish community identifying under-represented, existing as expected, over-abundant, missing, and introduced species in the Lamprey Designated River. Anadromous species expected to occur during seasonal migration periods or fresh water life-history bio-periods are also identified. Definitions of abbreviated terms are given within Table 2 caption.

Species	Proportion of Target Fish Community	Proportion of Existing Fish Community	Percent Deviation	Native or Introduced	Habitat use Classification	Pollution Tolerance	Thermal Regime
Underrepresented fish species							
American Eel[1]	10%	5%	56%	N	MG*	T	Eurythermal
Blacknose Dace	3%	0.3%	90%	N	FS	T	Eurythermal
Chain Pickerel	2%	1%	75%	N	MG	M	Warm
Atlantic Salmon[1]	2%	0.2%	91%	N	FS	I	Cold
Brown Bullhead	2%	0.2%	90%	N	MG	T	Warm
Creek Chubsucker	2%	0.3%	78%	N	FS	I	Eurythermal
Redfin Pickerel	2%	0.1%	94%	N	MG	M	Warm
Fish species recorded as expected							
Common Shiner	31%	34%	9%	N	FD	M	Eurythermal
Fallfish	16%	12%	22%	N	FS	M	Eurythermal
Common White Sucker	8%	5%	34%	N	FD	T	Eurythermal
Longnose Dace	6%	5%	27%	N	FS	M	Eurythermal
Yellow Perch	2%	1%	33%	N	MG	M	Eurythermal
Bridle Shiner	1%	1%	34%	N	MG	I	Warm
Overly abundant fish species							
Redbreast Sunfish	5%	15%	190%	N	MG	M	Warm
Pumpkinseed	4%	6%	54%	N	MG	M	Warm
Missing fish species							
Brook Trout	1%	-	100%	N	FS	I	Cold
Creek Chub	1%	-	100%	N	FS	T	Eurythermal
Swamp Darter	1%	-	100%	N	MG	M	Warm
Introduced species present within the existing fish community (considered overly abundant)							
Bluegill	-	6%	N/A	I	MG	T	Warm
Smallmouth Bass	-	2%	N/A	I	MG	M	Eurythermal
Largemouth Bass	-	2%	N/A	I	MG	M	Warm
Yellow Bullhead	-	1%	N/A	I	MG	T	Warm
Black Crappie	-	0.3%	N/A	I	MG	M	Warm
Rock Bass	-	0.3%	N/A	I	MG	M	Eurythermal
Brown Trout	-	0.05%	N/A	I	FD	I	Cold
Rainbow Trout	-	0.02%	N/A	I	FD	I	Cold
Native fish species currently or historically present within the Lamprey River Designated Reach missing from the Target Fish Community							
Golden Shiner	-	4%	N/A	N	MG	T	Eurythermal
Banded Sunfish	-	Present**	N/A	N	MG	M	Warm
Anadromous species expected to be present within the Lamprey River during seasonal spawning migration and freshwater life-stage bio-periods							
Alewife[1] [2]	Expected	Present	N/A	N	FD	M	Eurythermal
Blueback Herring[1] [2]	Expected	Present	N/A	N	FD	M	Warm
American Shad[1] [2]	Expected	Not Sampled	N/A	N	FD	M	Warm
Sea Lamprey (adult)[1] [2]	Expected	Not Sampled	N/A	N	FD	M	Eurythermal
Sea Lamprey (ammocoete)[1]	Expected	Not Sampled	N/A	N	FD	M	Eurythermal

[1] Diadromous species

[2] Anadromous pulse species (non-resident)

*American eel is a fluvial dependent (FD) macrohabitat generalist (MG) as this species is dependent upon fluvial conditions for migratory purposes

**Banded sunfish were not sampled during the Lamprey River Baseline Fish Sampling (NHDES) efforts but have been previously recorded within the Lamprey River

Discussion

The TFC model presented here provided us with the minimal amount of information deemed necessary to evaluate the existing fish community of the Lamprey Designated River. The computational framework of the TFC model accounted for spatial and temporal variations as well as potentially missing or under-represented fish species within individual reference rivers and created a robust representation of the expected native fish community of the Designated River. Multi-scale comparisons between the TFC model and the existing fish community allowed us to identify deviations from reference conditions (TFC) and to infer potential reasons for such deviations as they may relate to instream habitat and flow conditions, water quality, or thermal regime. This information provides the basis for an assessment of the biological integrity of Lamprey River within the Designated River.

The initial list of fish species with known current or historic distributions within the Lamprey Designated River was established through reviews of Carpenter and Siegler's *Fishes of New Hampshire* (1947) and Scarola's, *Freshwater Fishes of New Hampshire* (1987), and recent fish survey data from the Lamprey River watershed (NHFGD, NHDES). Further review of Lee et al. *Atlas of North American Freshwater Fishes* (1980) and Schmidt's, *Zoogeography of the Northern Appalachians* (1986) provided additional information on regional zoographic distributions of species and supplemented the initial list. This comprehensive list was then reviewed by local fisheries biologists familiar with the fish fauna of the Designated River, and species were added or removed accordingly. As a result, burbot *Lota lota*, central mudminnow *Umbra limi*, longnose sucker *catostomus catostomus*, margined madtom *Noturus insignis*, northern pike *Esox lucius*, and walleye *Stizostedium vitreum* were removed from the list. Rainbow smelt *osmerus mordax*, an anadromous species which occurs within Great Bay, was also removed from this list due to the belief that the historical natural falls at the present-day Macallen Dam site acted as a natural barrier to this species and would have prevented them from migrating past this point and into the Designated River (TNC 2006, Patterson 2007).

Diadromous species were included in this list because of the importance of maintaining and restoring populations of these fish within the State of New Hampshire and particularly within the Lamprey River Watershed (TNC 2006). The Lamprey River is considered to be one of the most important rivers within the State of New Hampshire for diadromous fish. Alewife, American eel, Atlantic salmon, and blueback herring currently exist within the Lamprey River (NHDES 2005) and were included in the list of expected species. It was determined that the historical distributions of American shad and sea lamprey within New Hampshire included the Designated segment of the Lamprey River (Jackson 1922, TNC 2006). Hence, these species were also included. The final list contained a wide range of species and families that are indicative of the fish faunal composition within low-gradient, low-elevation, acidic streams of the Northeastern Coastal Zone ecoregion and provided a feasible and comprehensive summary of the current, historic, and potential fish fauna of the Designated River.

The process of selecting reference rivers for TFC models was standardized with the development of the Reference River Selection Model (RRSM) (Legros 2007b). The addition of this tool to the TFC methodology not only standardizes the process of selecting reference rivers, but also improves the efficiency of TFC model development,

and the legitimacy of any comparative analyses between a TFC and the existing fish community of a study stream. Because the RRSM is capable of automatically selecting potential reference rivers based on the actual geomorphic conditions and zoogeographic regional location of the study stream we can be confident that the appropriate rivers, and subsequently the appropriate fish data are used to develop a TFC. This capability is critically important to the TFC development process considering the known relationships between stream geomorphology, hydraulics, zoogeography and fish community composition (Gorman and Karr 1978, Statzner et al. 1988, Angermeier and Winston 1998, Lamouroux et al. 1999, Lamouroux et al. 2002).

However, even with the improved ability to select potential reference rivers which are highly similar to the study stream, the actual number of ecologically suitable reference rivers may be limited. For instance, despite the fact that the RRSM identified 64 *potential* reference rivers for the Designated River, only a fraction of those rivers contained the adequate fish data and un-impaired ecological conditions required to qualify them as *suitable* reference rivers for the development of a TFC. Finding enough low impact reference rivers to provide adequate fish data for calculation of the TFC was problematic due to the fact that low gradient, coastal, fourth-order streams are often associated with anthropogenic alterations (e.g. dams, residential development, water withdrawals). Many potential reference rivers of the Lamprey River exhibited such impacts and could not be used. Because of the lack of suitable reference rivers, the initial set of suitable rivers consisted of only four rivers and was not adequate for the development of a TFC. As a result, two potential reference rivers (Cocheco and Isinglass Rivers) that are affected by ecological impairments, and would not have otherwise been considered, were included. An examination of the fish data from these rivers revealed fish assemblages that contained species which were appropriate for the Lamprey TFC and were not indicative of impacted habitat conditions. The inclusion of these two rivers accounted for two important fish species, bridle shiner and swamp darter, that would not have been accounted for in a TFC developed without these two rivers. Among the six reference rivers, these two rivers are geographically closest to the Designated River. Given the circumstances it was deemed reasonable, justifiable, and necessary to include these rivers and their fish data in the development of the TFC.

Among diadromous fish species, specific proportions could not be defined for alewife, American shad or blueback herring within the TFC. These anadromous species are only present within rivers for short periods of time during migratory pulses or their freshwater juvenile life-stages. This limits the availability and accuracy of abundance data within selected reference rivers. Proportions of another anadromous species, sea lamprey, also could not be specified within the TFC because of this species' habitat-use behavior during its freshwater juvenile life-stages. Sampling of this species can be difficult given that sea lamprey burrow into the sediment and filter-feed from this stationary position in a fashion more similar to a freshwater mussel than a fish, again resulting in limited or inaccurate data and making the identification of appropriate proportions of these species difficult. While specific proportions were not specified for any of these species, they are identified in the TFC as expected to be present.

The decision to include and specify proportions for Atlantic salmon and American eel within the Lamprey TFC resulted from the facts that both of these species are present within the river year-round, spend multiple years of their life history cycle within freshwater, are currently present within the Designated River (NHDES 2005), and are

species of conservation concern within the State of New Hampshire (NHFGD 2005). The presence of these species within the selected reference rivers reaffirmed the appropriateness of our decision to include these species within the TFC and provided the data necessary to generate their expected proportions. However it is possible that the expected proportions of these species specified within the TFC may not be the most accurate estimate given that the complicate life-history traits associated with the diadromy of these two species have resulted in their declines throughout the region as a result of migratory passage barriers. The effects of such barriers extend beyond the immediate area of the barriers themselves and affect entire watersheds where such barriers occur. Despite the fact that the selected reference rivers were generally free of obstructions to fish passage and flow the proportions of American eel and Atlantic salmon within these rivers may still have been affected by obstructions within the watershed but outside of the selected reference sections. For this reason, proportions of these species should be treated as estimates based on the best available data.

The final TFC developed for the Lamprey River is a robust and complete composition of the species expected to occur within lowland, coastal, fourth order streams and includes many species unique to this macrohabitat type, namely, bridle shiner, redfin pickerel, and swamp darter. The only species missing from the TFC that *should* have been accounted for is banded sunfish. The patchy and limited distribution of this species make it a species of conservation concern within the State of New Hampshire and explains the difficulty in accounting for this species from Reference River data. While this species was not collected during the Lamprey River Baseline Fish Community Sampling (NHDES 2005), it has been recorded within the Lamprey River in the past (Carroll 1996, NHFGD 1983-1985) and is still believed to be a member of the existing fish community.

A multi-level comparison between the TFC model and the existing fish community which was conducted at both the species-specific level and the species-guild level, allowed for a more complete assessment of the existing fish community than a single-level comparison would have. A comparison of species specific differences alone could have been affected by the natural variation of species compositions between the reference rivers, while a more generalized comparison of species- guilds, when considered alone, would not have specified missing, under-represented, over-abundant, or non-native species within the existing fish communities. An evaluation of the existing fish community, which took into consideration comparisons between TFC model and the existing fish community at both the species-specific *and* species-guild levels, accounted for the deficiencies that either comparison alone would have exhibited.

Three species (brook trout, creek chub, and swamp darter) were missing from the existing fish community, while two others (redbreast sunfish and pumpkinseed) were found in over-abundant proportions, and seven more (American eel, blacknose dace, chain pickerel, Atlantic salmon, brown bullhead, creek chubsucker, and redfin pickerel) were under-represented. Six species were recorded in proportions similar to expected (TFC) proportions. Two native species (banded sunfish and golden shiner) which were not members of the TFC, and eight non-native species (bluegill, smallmouth bass, largemouth bass, yellow bullhead, black crappie, rock bass, brown trout, and rainbow trout) were sampled within the Designated River. Of the six diadromous species expected to occur within the Designated River, four (Alewife, American eel, Atlantic salmon, and blueback herring) were recorded within the existing fish community. Four

(common shiner, fallfish, common white sucker, and longnose dace) out of the top five species within the TFC were recorded as expected, while the fifth (American eel) was only slightly under-represented. Both of the over-abundant species (redbreast sunfish and pumpkinseed) were warm-water, macrohabitat generalist species. The only species missing from the existing fish community were the three lowest ranking members of the TFC.

When community comparisons were made at the species-guild level based on habitat-use, pollution tolerance, and thermal regime classification guilds the existing fish community showed a high affinity to the TFC in all three comparisons. The existing fish community was most similar (91% affinity) to the TFC with regard to pollution tolerance classification guilds. Moderately tolerant and tolerant species occurred in proportions similar to expected (TFC) proportions (slightly higher and slightly lower, respectively), while pollution intolerant species occurred in proportions considerably less (71% deviation) than expected (**Table 8a**). The substantially lower proportion of pollution intolerant species did not coincide with any major differences in proportions of moderately tolerant or tolerant species between the two communities and is not necessarily indicative of impaired water quality conditions. In fact, the proportion of pollution tolerant species within the existing community was lower than the expected proportion. Given that the under-abundance of pollution intolerant species did not coincide with an overabundance of pollution tolerant species, it is not clear whether the under-abundance of pollution intolerant species can be attributed to pollution.

The comparison of thermal regime classification guilds between the TFC and the existing fish community also revealed a similar affinity (86%). However, obvious difference were observed between the two communities with regard to the compositions of warm-water and cold-water species-group guilds. The proportion of cold-water species within the existing fish community was substantially less than the expected proportion (93% deviation), while the proportion of warm-water species was considerably higher (80% deviation) (**Table 8b**). Based on this analysis it would appear that the biological integrity of the Lamprey Designated River may be affected by conditions that have created a thermal regime of water temperatures that are warmer than those that would support the natural fish community defined by the TFC.

The comparison of the habitat-use classification guilds of the existing fish community to those of the TFC also showed a high community affinity (86%). Comparisons of the individual habitat-use guilds between the two communities also revealed similar proportions. The proportion of fluvial dependent species within the existing fish community was identical to the expected proportion. Proportions of fluvial specialist and macrohabitat generalist species were fairly similar (deviations of 44% less and 45% greater, respectively) (**Table 8c**). While these guild proportions deviated by less than the 50% deviation value selected as indicative of an obvious difference between expected and existing conditions, it is still important to recognize that the proportion of fluvial specialist species was lower than expected whilst the proportion of macrohabitat generalist species was greater than expected.

Table 8. Comparison of the Lamprey Designated River TFC and existing fish community species-group classification guilds indicating - guild and community absolute differences, community affinity, and guild deviation percentages.

a.

Pollution Tolerance Classification Guild	Expected Proportion	Existing Proportion	Absolute Difference	Percent Deviation
Intolerant	7%	2%	5%	71%
Moderate	69%	78%	9%	13%
Tolerant	24%	20%	4%	18%
Totals:	100%	100%	18%	
percent affinity:			***91%***	

b.

Thermal Regime Classification Guild	Expected Proportion	Existing Proportion	Absolute Difference	Percent Deviation
Cold water	4%	0%	4%	93%
Eurythermal	79%	69%	10%	13%
Warm water	17%	31%	14%	80%
Totals:	100%	100%	28%	
percent affinity:			***86%***	

c.

Habitat-Use Classification Guild	Expected Proportion	Existing Proportion	Absolute Difference	Percent Deviation
Fluvial Specialist	31%	18%	14%	44%
Fluvial Dependent	39%	39%	0%	0%
Macrohabitat Generalist	30%	43%	13%	45%
Totals:	100%	100%	27%	
percent affinity:			***86%***	

The Lamprey Designated River supports a fish community similar to the fish community expected to occur under natural conditions within a fourth order, low gradient, low elevation, coastal stream of the Northeastern Coastal Zone. Overall, the community composition is indicative of a relatively healthy fish assemblage dominated by fluvial species. The existing fish community exhibited a 71% affinity similarity measurement to the TFC. This affinity value is higher than any other affinity values measured within previous TFC analyses conducted within this region (Bain and Meixler 2000, Meixler 2005, Kearns et al. 2005, Legros 2007a, Legros 2007b, Parasiewicz et al. 2007). This would suggest that compared to other developed rivers within the region the Lamprey Designated River possesses relatively high biological integrity. However, this analysis illustrated the impacts that un-naturally impounded areas created by dams may be having on the existing fish community with regard to habitat and temperature conditions. Specifically, that there is an under-abundance of cold-water species

coinciding with an over-abundance of warm-water species and that there is a lesser proportion of fluvial specialists and a greater proportion of macrohabitat generalists than expected. Furthermore, it is possible that non-native fish species may be having a negative impact on native stream fish communities and particularly on the native macrohabitat generalists of the Lamprey River.

There is considerable evidence to suggest that the impounded areas of the Lamprey River created by dams (e.g. Wiswall Dam Impoundment, Macallen Dam Impoundment) are having a substantial impact on the fish community composition of the Designated River; the effect of which is illustrated by an overabundance of macrohabitat generalist species. In particular, there is an overabundance of *non-native* macrohabitat generalist species which appear to be out-competing native macrohabitat generalists within those areas. The Macallen Dam impoundment alone accounted for 60% of the non-native fish sampled within the Lamprey Designated River while accounting for only 8% of the total fish captured from all sections (NHDES 2005). The Wiswall Dam impoundment accounted for an additional 13% of the non-native fish sampled and only 14% of the total catch (NHDES 2005). The catch from these two sections alone accounted for 73% of the *non-native* fish caught while accounting for only 22% of *all* the fish caught during the Lamprey River Baseline Fish Community Sampling (NHDES 2005). It is fair to deduce that the dam impoundments (two sections) accounted for a disproportionate amount of the non-native fish sampled within the entire Designated River (eight sections). Investigating this matter further may be important to the preservation of native fish communities within the Designated River. In particular, the effects that these impoundments and non-native species may be having on native macrohabitat generalist species which are of conservation concern within the State of New Hampshire (e.g. banded sunfish, bridle shiner, redfin pickerel, and swamp darter) should be investigated, monitored and addressed in the interest of maintaining and preserving these species to meet the goals identified within the State's recent Wildlife Action Plan (NHFGD 2005).

The TFC model identified the core group of native fish species expected to dominate the Designated segment of the Lamprey River under un-impacted conditions. Based on their composition within the TFC, American eel, common shiner, common white sucker, fallfish, longnose dace, and redbreast sunfish were selected as indicator species for the MesoHABSIM modeling process. Atlantic salmon will also be included as an indicator fish species due to their specific habitat requirements and concerns related to the conservation of this species. The habitat suitability requirements (based on logistic regression coefficients developed from empirical fish capture data) and weighted proportions of these species within the TFC model will be used to train the Lamprey River MesoHABSIM model to predict the necessary quantity of instream flow required within the river to provide and maintain sufficient amounts of habitat to support their biological needs during different seasons or bio-periods (NHDES 2007). Methods of identifying habitat-related instream flow thresholds are crucial to sustaining "healthy" ecological communities given the numerous competing needs for limited water resources throughout the Northeast region. The TFC and MesoHABSIM approaches, used in conjunction, has been shown to be a highly effective method of accomplishing this task for multiple rivers throughout the Northeast (Parasiewicz 2005, Parasiewicz et al. 2007a, Parasiewicz et al. 2007b, NHDES 2007).

In addition to providing the indicator species used for habitat modeling, the TFC model served as an evaluation tool for the assessment the biological integrity of the Lamprey Designated River based on a comparison with the existing fish community composition. An inference-based approach, deriving from comparisons between fish species habitat use, pollution tolerance, and thermal regime guilds, as previously described and discussed, was used to identify potential causes for deviations of fish species-proportions from those specified within the TFC model. The analysis provided an adequate amount of information to assess the biological integrity of the Designated River with regard to existing macrohabitat and water quality (including temperature) conditions. This analysis and report provide a baseline condition which can be used as a gauge to guide future watershed management objectives and measure the results of any physical or biological rehabilitation efforts that may occur within the Designated segment of the Lamprey River. Stream habitat rehabilitation measurement "gauges", such as TFC models, may prove increasingly necessary and important as national fisheries management agencies and non-government organizations alike begin to focus on aquatic species habitat conservation as a crucial aspect of the conservation of our nations fisheries resources through efforts such as the National Fish Habitat Initiative (NFHI 2006).

Previous TFC studies relied on semi-subjective decisions to designate over-abundant and under-abundant species and did not identify any objective methodology involved in the decision-making process. While this analysis used a percent deviation calculation to objectively make these decisions, it is not without its limitations. For example, the 50% deviation value used to delineate over-abundant or under-abundant species within the existing fish community was arbitrarily selected. While this value is used here to indicate obvious differences between the two communities, it is not conclusive whether or not these differences are statistically significant. A statistical analysis of the ranges of variability between species and species groups among reference rivers is necessary to identify the appropriate degree of deviation value that should be used to indicate significant differences (i.e., over-abundant, under-abundant). Given that the percent deviation analysis is a recent addition to the TFC methodology (Legros 2007) such analyses have not yet been conducted. However, with the recent completion of multiple TFC studies, the data for such analyses exists and should be examined to identify statistically significant ranges of deviation for the analysis of future TFC models. Likewise, analyses of the ranges of affinity values between TFC models and existing fish communities in previously conducted studies should be assessed to identify the degree to which affinity value is indicative of the biological integrity of aquatic systems (i.e., un-impacted, slightly impacted, moderately impacted, severely impacted).

Acknowledgements

The Northeast Instream Habitat Program and Rushing Rivers Institute thank C. Wayne Ives of the New Hampshire Department of Environmental Services, Thomas Ballestero of the University of New Hampshire, and Al Larson of Normandeau Associates, and the Lamprey River Technical Review Committee for their guidance during the development of the Lamprey Designated River Target Fish Community and for reviewing this report. We would also like to express our gratitude to the following people for providing fish survey data and offering their professional knowledge and expert opinions to this project: David Neils (New Hampshire Department of Environmental Services), John Magee (New Hampshire Fish and Game Department), Todd Richards, Leanda Fontaine, and Michael Kashiwagi (Massachusetts Division of Fisheries and Wildlife), Neal Hagstrom (Connecticut Department of Environmental Protection), and Alan Libby (Rhode Island Department of Environmental Management). We also recognize the importance of the previous and on-going Target Fish Community work of others which has contributed to the work presented here. Specifically we would like to acknowledge and thank Mark Bain and Marcy Meixler (Cornell University), Vernon Lang (U.S. Fish and Wildlife Service), Ralph Abele (U.S. Environmental Protection Agency), David Armstrong and Gene Parker (U.S. Geological Survey), Margaret Kearns (Massachusetts Riverways Program), and Todd Richards and Michael Kashiwagi (Massachusetts Division of Fisheries and Wildlife).

References

Angermeier, P.L., and M.R. Winston. 1998. Local vs. regional influences on local diversity in stream fish communities of Virginia. Ecology 79:911-922.

Armstrong, D.S., Richards, T.A., and Parker, G.W. 2001. Assessment of habitat, fish communities, and streamflow requirements for habitat protection, Ipswich River, Massachusetts, 1998-99: U.S. Geological Survey Water-Resources Investigations Report 01-4161, 72 p.

Bain, M.B. and M.S. Meixler. 2000. Defining a Target Fish Community for Planning and Evaluating Enhancement of Quinebaug River in Massachusetts and Connecticut. New York Cooperative Fish and Wildlife Research Unit, Cornell University, 2000.

Bain, M.B., J.T. Finn, and H. E. Booke. 1988. Streamflow regulation and fish community structure. Ecology 69:382–392.

Bain, M.B., and J.G Knight. 1996. Classifying stream habitat using fish community analyses. Proceedings of the 2nd IAHR Symposium on Habitat Hydraulics (Ecohydraulics 2000). Leclerc, M., Capra, H., Valentin, S., Boudreault, A., Côté, Y., (eds),INRS-Eau, Québec, p. B107-B117.

Bain, M. B., Travnichek, V. H. 1996. Assessing impacts and predicting restoration benefits of flow alterations in rivers developed for hydroelectric power production. Proceedings of the 2nd IAHR Symposium on Habitat Hydraulics (Ecohydraulics 2000). Leclerc, M., Capra, H., Valentin, S., Boudreault, A., Côté, Y., (eds), INRS-Eau, Québec, p. B543-B552.

Becker, G.C. 1983. Fishes of Wisconsin. The University of Wisconsin Press, Madison, Wisconsin. 1081 pp.

Burr, B.M. & M.L. Warren, Jr. 1986. A distributional atlas of Kentucky fishes. Kentucky nature Preserves Commission, Scientific and Technical Series Number 4, Carbondale, Illinois. 398 pp.

Carpenter, R.G., and H.R. Siegler. 1947. A Sportsman's Guide to the Freshwater Fishes of New Hampshire. The New Hampshire Fish and Game Commission.

Carroll, D. 1996. Lamprey River Turtle and Ecology Investigations: Principal Findings.

Ecoregions of the Coterminous United States [map]. Annals of the Association of American Geographers, 1987. Using: ArcMap [GIS software]. Version 8.3. Redlands, CA: Environmental Systems Research Institute, Inc., 1999-2002.

Fausch, K.D., J. Lyons, J.R. Karr, and P.L. Angermeier. 1990. Fish communities as indicators of environmental degradation. American Fisheries Society Symposium 8: 123-144.

Gorman, O.T., and J.R. Karr. 1978. Habitat structure and stream fish communities. Ecology 59:507-515.

Halliwell, D. B., R. W. Langdon, R. A. Daniels, J. P. Kurtenbach, and R. A. Jacobson. 1999. Classification of freshwater fish species of the northeastern United States for use in the development of indices of biological integrity, with regional applications. Pages 301-333 in T. P. Simon, editor. Assessing the sustainability and biological integrity of water resources using fish communities. CRC Press, Boca Raton, Florida.

Hartel, K.E., D. B. Halliwell, and A. E. Lauer. 2002. Inland Fishes of Massachusetts. Massachusetts Audubon Society, Lincoln, Massachusetts.

Hughes, R.M. 1995. Defining acceptable biological status by comparing with reference conditions. Pp. 31-47, *In* W.S. Davis and T.P. Simon (Eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishing Co. Boca Raton, FL. 415 pp.

Jackson, C.F. 1922. Ecological features of Great Bay, New Hampshire, and a preliminary checklist of its fish. Ecology 3(1): 48-54.

Jenkins, R. E. and N. M. Burkhead. 1994. Freshwater Fishes of Virginia. American Fisheries Society, Bethesda, Maryland.

Karr, J.R. 1981. Assessment of biotic integrity using fish communities. Fisheries 6(6): 21-27.

Kearns, M., T. Richards, A. Madden, R. Abele, V. Lang, R. Maietta, and D. Armstrong. 2005. Development of a Target Fish Community for the Housatonic River, Massachusetts. Draft Report. 18 p.

Lamouroux, N.J., M. Olivier, H. Persat, M. Pouilly, Y. Souchon, and B. Statzner. 1999. Predicting community characteristics from habitat conditions: fluvial fish and hydraulics. Freshwater Biology 42:1-25.

Lamouroux, N.J., N.L. Poff, and P.L. Angermeier. 2002. Intercontinental convergence of stream fish community traits along geomorphic and hydraulic gradients. Ecology 83(7): 1792-1807.

Lang, V., R. Abele, D. Armstrong, T. Richards, P. Brady, R. Iwanowicz, R. Maietta, L. Wagner, J. MacDougall, and K. Mackin. 2001. Ipswich River Target Fish Community. Ipswich River Fisheries Restoration Task Group. Report. 6 p. Appended to *Ipswich River Fisheries Restoration Report*. Ipswich River Watershed Association. 2002.

Langdon, R.W. 2001. A preliminary index of biological integrity for fish assemblages of small coldwater streams in Vermont. Northeastern Naturalist 8(2):219-232

Lee, D.S., C.R. Gilbert, C.H. Hocutt, R.E. Jenkins, D.E. McAllister, & J.R. Stauffer, Jr. 1980. Atlas of North American freshwater fishes. North Carolina State Museum of Natural History. 854 pp.

Legros, J.D. 2007a. Development and analysis of reference fish community models to evaluate the existing fish communities of the Pomperaug River Watershed, Connecticut. Northeast Instream Habitat Program, University of Massachusetts – Amherst. Report. 42 p.

Legros, J.D. 2007b. Development and analysis of Target Fish Community models to evaluate the status of the existing fish communities in the Upper and Lower Souhegan River, New Hampshire. Northeast Instream Habitat Program, University of Massachusetts – Amherst. Report. 33 p. *Appendix 6* within *Souhegan River Protected Instream Flow Report*, University of New Hampshire, University of Massachusetts, and Normandeau Associates. New Hampshire Department of Environmental Services, 2007. NHDES-R-WD-06-50.

Lyons, J., Wang, L., and Simonsen T.D. 1996. Development and validation of an index of biological integrity for coldwater streams in Wisconsin. North American Journal of Fisheries Management, 16 (2): 241-256.

Meixler, M.S. 2005. Defining a Target Fish Community for the Charles River in Massachusetts. Charles River Watershed Association, Waltham, Massachusetts. Report. 26 p.

National Fish Habitat Initiative (NFHI). 2006. A Framework for Assessing the Nation's Fish Habitat. National Fish Habitat Science and Data Committee. Report. 75 p.

National Fish Habitat Initiative (NFHI). 2006. National Fish Habitat Action Plan. Report. 28 p.

New Hampshire Department of Environmental Services (NHDES). 2005. Lamprey River Baseline Fish Sampling: August 25-29, 2003. Report. 27 p.

New Hampshire Department of Environmental Services (NHDES). 2007. Souhegan River Protected Instream Flow Report, University of New Hampshire, University of Massachusetts, and Normandeau Associates. New Hampshire Department of Environmental Services, 2007. NHDES-R-WD-06-50.

New Hampshire Fish and Game Department (NHFGD). 1983-1985. Lamprey River Mainstem fish sampling survey data.

New Hampshire Fish and Game Department (NHFGD). 2005. New Hampshire Wildlife Action Plan. Report.

Novak, M.A. and R.W. Bode. 1992. Percent model affinity: a new measure of Macroinvertebrate community composition. Journal of the North American Benthological Society 11(1):80-85

Olivero, A.P. 2003. Planning methods for ecoregional targets: Freshwater aquatic ecosytems and networks. M.G. Anderson and S.L. Bernstein (Editors). The Nature Conservancy. Conservation Science Support, Northeast and Caribbean Division, Boston, MA.

Omernik, J. M. 1987. Ecoregions of the coterminous United States. Map (scale 1:7,500,000). Annals of the Association of American Geographers 77(1):118-125.

Parasiewicz, P. 2001. MesoHABSIM: A concept for application of instream flow models in river restoration planning. Fisheries 26 (9): 6-13.

Parasiewicz, P., J.L. Legros, J.N. Rogers, and M.J. Wirth. 2007a. Assessment and restoration of instream habitat for the Pomperaug, Nonnewaug, and Weekeepeemee Rivers of Connecticut. Northeast Instream Habitat Program, University of Massachusetts – Amherst. Report. 103 p.

Parasiewicz, P., J.N. Rogers, J.D. Legros, and M.J. Wirth. 2007b. Assessment and restoration of instream habitat of the Eightmile River in Connecticut: Developing a MesoHABSIM model. Northeast Instream Habitat Program, University of Massachusetts – Amherst. Report. 62 p.

Parasiewicz P. 2005. Ecohydrology study of the Quinebaug River – Final Report for New England Interstate Water Pollution Control Commission. Ithaca, NY. 385 pp.

Parker, G.W., Armstrong, D.S., and Richards, T.A. 2004. Comparison of methods for determining streamflow requirements for aquatic habitat protection at selected sites on the Assabet and Charles Rivers, Eastern Massachusetts, 2000-02: U.S. Geological Survey Scientific Investigations Report 2004-5092, 72 p.

Patterson, C. (cpatterson@nhfgd.org). (2007, April 28). Lamprey River instream flow study questions. Email to J. Magee (john.a.magee@wildlife.nh.gov).

Pflieger, W.L. 1975. The Fishes of Missouri. Missouri Department of Conservation, Springfield, Missouri. 372 pp.

Robinson, H.W. & T.M. Buchanan. 1988. Fishes of Arkansas. The University of Arkansas Press, Fayetteville, Arkansas. 536 pp.

Scarola, J.F., 1987. Freshwater Fishes of New Hampshire. New Hampshire Fish and Game Department, Concord, NH.

Schmidt, R. E. 1986. Zoogeography of the northern Appalachians. Pages 137-159 in C.H. Hocutt and E. O. Wiley, editors. The Zoogeography of North American Freshwater Fishes. John Wiley & Sons, New York, New York.

Scott, W. B. & E. J. Crossman. 1973. Freshwater fishes of Canada. Bulletin 184. Fisheries Research Board of Canada, Ottawa. 966 pp.

Statzner, B., J.A. Gore, and V.H. Resh. 1988. Hydraulic stream ecology: observed patterns and potential applications. Journal of the North American Benthological Society 7:307-360.

The Nature Conservancy Stream Datasets and Ecological Systems Datasets, Draft [maps, data]. Boston, MA: The Nature Conservancy, 2003. Using: ArcMap [GIS software]. Version 8.3. Redlands, CA: Environmental Systems Research Institute, Inc., 1999-2004.

The Nature Conservancy (TNC). 2006. Great Bay Estuary Restoration Compendium. Report. 65 p.

Trautman, M. B. 1981. The fishes of Ohio. Ohio State University Press, Columbus, Ohio.